RESEARCH ARTICLE

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Characterization of Zeolite as an Adsorbent for Capturing CO_2

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The characterization of zeolites as an adsorbent for capturing CO_2 from biogas has been done chemically and physically. The chemically treatment is using H_2SO_4 as an activator with varying concentrations in the range of 5%–30% and physically treatment is calcination at 500 °C for 4 hr. Adsorption process carried out by flowing CO_2 synthetic gas (98.86%) from the bottom of the adsorber column with a flow rate of 0.22 cc/min until 0.58 cc/min. Absorber column have a diameter 5 cm and height of 30 cm, height of adsorbent 28 cm and the grain size of the zeolite −20/+28 mesh. The research resulted in the best condition in chemical activation of 25% H_2SO_4 and calcination increasing ratio Si/Al of 5.5 to 9.73. Characterization of zeolites have a total pore volume of 15.001 cc/g, pore surface area of 998.032 m^2/g, mean pore radius 28.997 Å and CO_2 absorption capacity of about 75.5% at the gas rate penetrating to the adsorber of 0.22 cc/minute.

Keywords: Zeolite, Adsorbant, Calcination.

1. INTRODUCTION

Waste liquid vinasse from alcohol industry have been processed anaerobically using activated sludge to produced biogas. The waste water treatment of Vinasse from the fermentation industry of anaerob alcohol taken from the activated sludge of cow dung treatment can produce biogas containing methane: (CH_4) 42,89–58,06%, and carbon dioxide: 41,94%–58,11%.[1] The gas content of CH_4 more than 60% can be obtained by removing CO_2 gas using some adsorbent. Adsorbent is a material which is capable of adsorbing the gas based on its porous characteristics. This porous material was chosen because its inside surface was wider than the outside one.[2]

The use of porous material like sepiolite, silica and zeolite as gas adsorbent has been very popular. The combination of Fe_2O_3 and Fe_3O_4 with monmorillonite to adsorb H_2S gas contained in biogas had been conducted.[3]

Meanwhile, used zeolit from faujasit of, NaX and NaY as an adsorbent to remove H_2S gas contained in biogas.[4] In order to get rid of CO_2 gas from the mixture of CH_4 gas and CO_2, we used sepiolit through pressure swing adsorption.[5] Based on the former research, it was stated that zeolit was capable of adsorbing the gas.

Zeolit is a compound of alumino hydrated silicate containing of the bond of hydrated SiO_4 and AlO_4 connected by some oxygen atom to form a framework. Furthermore, in zeolite framework, each Al atom has a negative properties. This condition can be neutralized by using the exchangeable cation. These cations which are easily to be exchanged are available in the zeolit framework. This might affect to the adsorption process and its thermal zeolit properties.[6] Furthermore, the type of cation enabling to adsorb zeolit can also be influenced by the percentage of Si/Al and its geometrical pores of zeolit as well as its inside surface width of pores and its shape.[7,8] The ratio change of Si/Al from zeolit is capable of changing the zeolit charge, so that finally it can change the number of counterweight cation. Less Al atom means that the amount of zeolite containing negative charge is less so that the counterweight cation contained in zeolite will also be less than that of the high zeolite having hydrophobic properties and having its affinity to hydrocarbon.

In line with the varieties of zeolit structure and its impurities available, it was suggested that before being used, zeolite had to be treated formerly which was called as activation process. In general, activation process to zeolit was conducted physically by heating it for several hours and chemically by using acid or base. Activation process of zeolite conducted chemically by using acid or base could be obtained that the activated zeolite by using acid or base would become more polar than that of the activated zeolite using acid.[9] The treatment using acid to the zeolit might cause the zeolite become more hydrophob so that its adsorption potency to the water would become less.[10]

Furthermore, the adsorption potency of gas was influenced by its adsorbent texture. Gas adsorption required some adsorbent of micro size ($d \ll 20$ Å) because gas had a molecule size, that was <4 Å.[11] Adsorption process of gas by adsorbent was affected by

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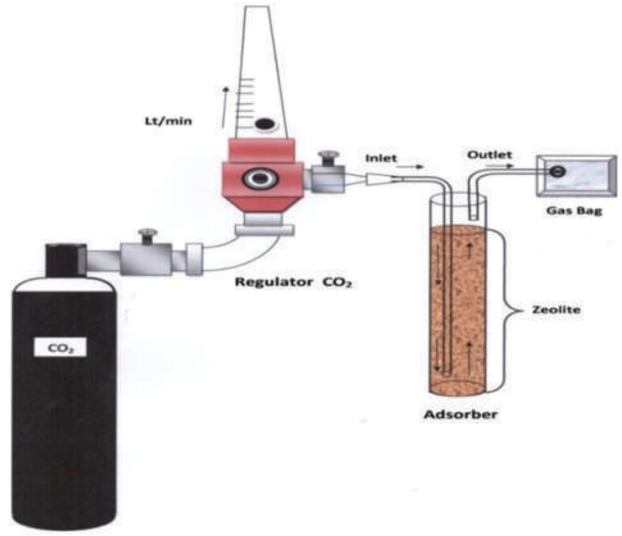

Fig. 1. Diagram of adsorption CO_2 process with zeolite adsorbent.

the interaction of van der waals related to polarisability of molecular adsorbant and adsorbent. The wider the surface of adsorbent, the more often the interaction of van der waals will happen. This might make the gas absorption become higher.[11] If the molecule size is compared with the size of pore adsorbent, the gas will be adsorbed into its adsorbent. This occasion is called sterical mechanism.[12] Based on this is it necessary to characterize zeolite.

2. METHODOLOGY

CO_2 gas adsorption using zeolite done using equipment such as arranged in Figure 1. The adsorption method is carried out experimentally in three stages. The first stage is the design of the adsorber column having a diameter of 5 cm, height 30 cm high and 28 cm of adsorbent high. The second stage is a zeolite having a grain size of −20/+28 mesh chemically activated using sulfuric acid with concentrations varied in the range 5% to 30%

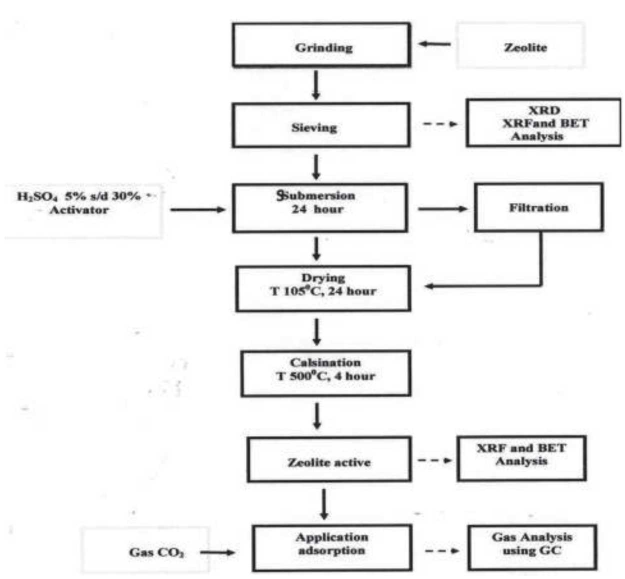

Fig. 2. Diagram of methodology.

while the activation is physically carried out calcination at a temperature of 500 °C for 4 hours. The third stage is the adsorption process conducted by flowing CO_2 gas 98.86% from the bottom of the adsorber column with a flow rate varies in the range of 0.22 cc/min up to 0.58 cc/min. Gas exit adsorbent accommodated in the gas bag for purposes of determining the levels of CO_2.

X-ray diffraction zeolite was do for to determine the constituent mineral zeolite, while the zeolite composition analysis using X-ray Fluorescence. Characterizations of zeolites were analyzed by gas-desorption N_2 adsorption using the equation Brunaurer, Emmet and Teller (BET) and gas out of the gas content of the adsorbent analyzed using GC.

3. RESULTS AND DISCUSSION

Figure 3 shows X-ray diffraction (XRD) pattern of particles zeolite, the components of zeolite mostly modernit and quartz.

Figure 4 shows the Si/Al ratio on particle zeolite before and after activation. The Si/Al ratio without activation is 5.5, while the activation of zeolite at a concentration of 25% H_2SO_4 produces Si/Al ratio reached 9.73.

The increasing the ratio of Si/Al resulted in a decrease in pore size due to Si–O chain is shorter than the chain Al–O so that the

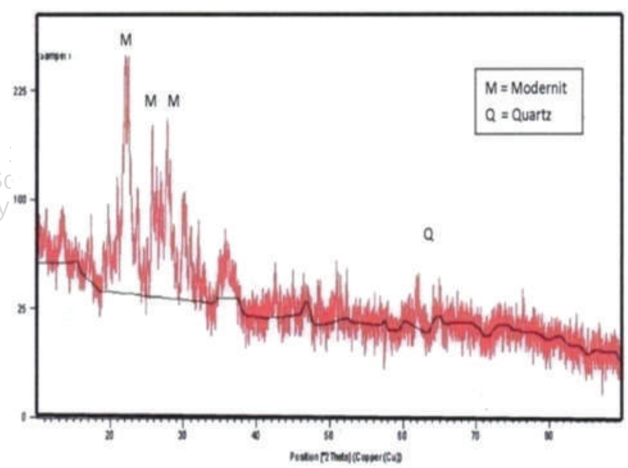

Fig. 3. X ray diffraction of zeolite particle.

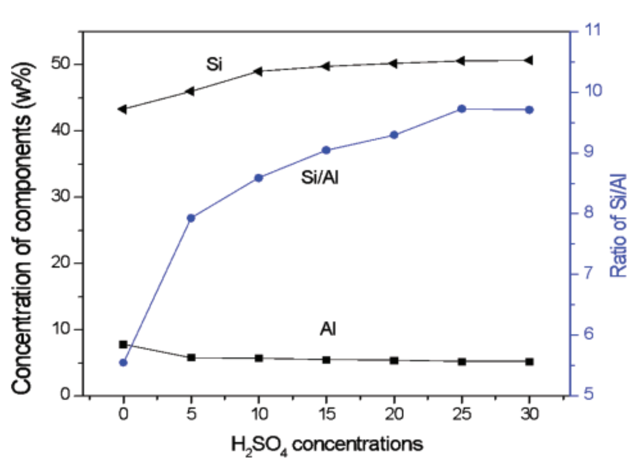

Fig. 4. Si/Al ratio on particle zeolite before and after activation.

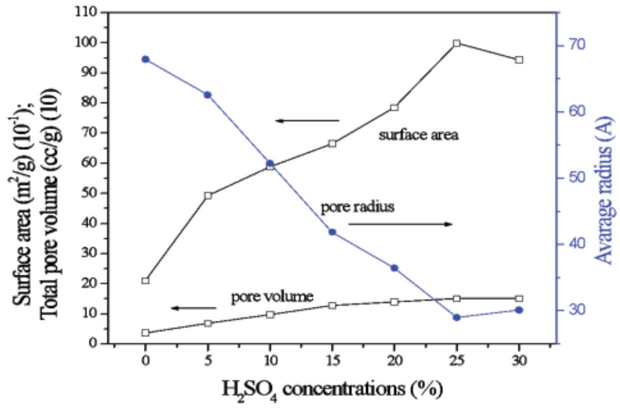

Fig. 5. Effect of H_2SO_4 on surface area, total pore volume and average pore radius of particle zeolite.

frame size is smaller. The decline was also accompanied by an increase in pore surface area thereby increasing contact between the adsorbent and the adsorbate (Fig. 5). Calcination aims to vaporize Bronsted bases and H_2O as well as arranging atoms mixed up to form stable metal oxides.

The surface area (BET) and total pore volume tends to increase with increasing concentration of H_2SO_4 activator, while the average pore radius decreases. The pore size of the adsorbent will affect the absorption of gas. Figure 5 shows the pore size of the zeolite ranges between 3.6 cc/g to 15.001 cc/g has the potential to absorb CO_2. CO_2 flow rate effect on the adsorption process. Figure 6 describes the ability of the zeolite to adsorb CO_2. Percentage of CO_2 gas adsorbed is increases as the size of the flow rate of CO_2 that enters the adsorber column. Differences on the increase in the percentage of CO_2 adsorbed are ranges from 5–11% for every decrease in the rate of CO_2 entry in the range of 0.22 cc/min to 0.58 cc/min. The percentage of CO_2 gas was adsorbed increased with increasing concentrations of H_2SO_4 activator. H_2SO_4 dissolves impurities that cover the pores, so that the zeolite pores to be open and the surface becomes more widespread. Figure 7 shows the percentage of CO_2 gas is adsorbed into the zeolite increased with increasing concentrations of H_2SO_4 activator further decreased at the rate of 30% activator. This is because the concentrated acid that causes the large number of Al-soluble so many atoms out of the zeolite framework structure of the zeolite causing damage. As a result, adsorption ability decreases.

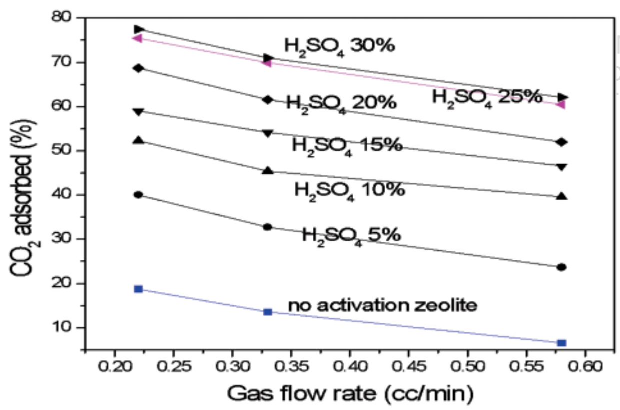

Fig. 6. Effect of gas flow rate on CO_2 adsorbed.

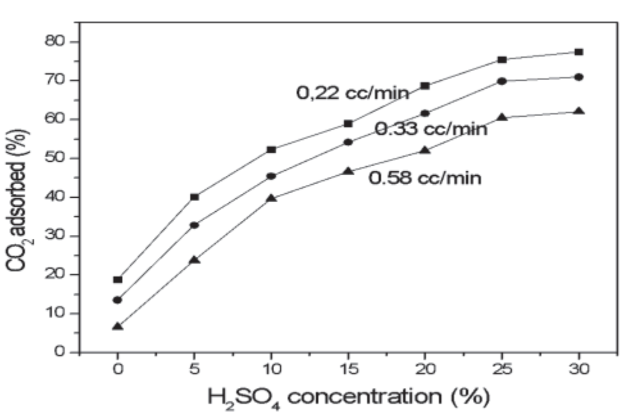

Fig. 7. Effect of H_2SO_4 concentrations on CO_2 adsorbed.

Table I. Components of zeolite (XRF).

		Concentration (%)					
Component	Blanco	H_2SO_4 5%	H_2SO_4 10%	H_2SO_4 15%	H_2SO_4 20%	H_2SO_4 25%	H_2SO_4 30%
Si	43.3	46	49	49.8	50.2	50.6	50.7
Al	7.8	5.8	5.7	5.5	5.4	5.2	5.22
Ca	11.9	15.9	13.8	15	12.4	13.1	14.4
K	12.3	10.4	10.6	10.3	10	9.22	10.2
Fe	8.75	7.25	6.7	6.57	6.24	5.07	6.26
Na	3.2	2.6	1.8	1.4	0.9	0.7	0.7

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4. CONCLUSIONS

Activated zeolite prepare by sulfuric acid as activator have done successfully. The percentage of CO_2 adsorbed dependent to the concentrations of H_2SO_4. The activation of zeolite using sulfuric acid can affect the value of ratio Si/Al. A good result of it could be obtained well if zeolite chemically treatment was conducted by using H_2SO_4 activator 25% and physically treatment is calcinations at 500 °C for 4 hr which could increasing ratio Si/Al of 5.5 to 9.73. Characterization of zeolites have a total pore volume of 15.001 cc/g, pore surface area of 998.032 m^2/g, mean pore radius 28.997 Å and CO_2 absorption capacity of about 75.5% at the gas rate penetrating to the adsorber of 0,22 cc/minute.

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